CLAIMS

What is claimed is:

1. An expandable reamer for drilling a subterranean formation, comprising:

a tubular body having a longitudinal axis and a leading end thereof for connecting to a pilot drill bit and a trailing end thereof for connecting to a drill string;

a drilling fluid flow path extending through the expandable reamer for conducting drilling fluid therethrough;

a plurality of generally radially and longitudinally extending blades carried by the tubular body, carrying at least one cutting structure thereon, wherein at least one blade of the plurality of blades is laterally movable;

a blade-biasing element for holding the at least one laterally movable blade at an innermost lateral position with a force, the innermost lateral position corresponding to no more than an initiai diameter of the expandable reamer;

a structure for retaining the at least one laterally movable blade at an outermost lateral position, the outermost lateral position corresponding to an expanded diameter of the expandable reamer; and

an actuation sleeve positioned along an inner diameter of the tubular body and configured to selectively prevent or allow drilling fluid communication with the at least one laterally movable blade according to a flow rate of drilling fluid passing therethrough.

2. The expandable reamer of claim 1, further comprising at least one fluid aperture disposed within the at least one laterally movable blade for communicating drilling fluid from an interior of the tubular body to an outer surface of the at least one laterally movable blade.

3. The expandable reamer of claim 2, wherein the at least one fluid aperture is oriented at an angle from a horizontal plane perpendicular to the longitudinal axis and toward the trailing end of the tubular body.

4. The expandable reamer of claim 1, wherein the at least one cutting structure comprises a plurality of superabrasive cutters.

5. The expandable reamer of claim 1, wherein the at least one cutting structure comprises a tungsten carbide compact.

6. The expandable reamer of claim 1, wherein the actuation sleeve is configured to increase a size of the drilling fluid flow path through the expandable reamer by way of selectively allowing drilling fluid communication with at least one alternative drilling fluid flow path while allowing drilling fluid to communicate with the at least one laterally movable blade.

7. The expandable reamer of claim 1, wherein a cross-sectional shape of the at least one laterally movable blade in a geometric plane substantially perpendicular to the lateral movement thereof comprises at least one of an oval, elliptical, and arcuate shape.

8. The expandable reamer of claim 1, wherein a cross-sectional shape of a portion of the at least one laterally movable blade capable of being positioned laterally outside of the tubular body in a geometric plane substantially perpendicular to the direction of lateral movement thereof comprises at least one of an oval, elliptical, and arcuate shape.

9. The expandable reamer of claim 1, further comprising:

a reduced cross-sectional area orifice for developing longitudinal force upon the actuation sleeve by way of drilling fluid flowing therethrough;

wherein a first longitudinal position of the actuation sleeve prevents drilling fluid from communicating with the at least one laterally movable blade and a second longitudinal position of the actuation sleeve allows drilling fluid to communicate with the at least one laterally movable blade.

10. The expandable reamer of claim 9, wherein the reduced cross-sectional area orifice is sized and configured to generate a selected magnitude of longitudinal force upon the actuation sleeve in relation to an expected drilling fluid flow rate.

11. The expandable reamer of claim 9, further comprising an actuation sleeve-biasing element for positioning the actuation sleeve in the first longitudinal position with a force.

12. The expandable reamer of claim 11, further comprising a pin affixed to the actuation sleeve, the pin disposed within a groove formed within a pin guide sleeve configured to selectively position the actuation sleeve.

13. The expandable reamer of claim 12, wherein the groove comprises alternating upward sloping and downward sloping arcuate paths formed at least partially along a circumference of the pin guide sleeve.

14. The expandable reamer of claim 13,

wherein the actuation sleeve-biasing element and the reduced cross-sectional orifice are sized and configured so that a drilling fluid flow rate equal to or exceeding a first selected value causes the pin and actuation sleeve to be longitudinally displaced substantially to a lower longitudinal extent of its associated arcuate path; and

wherein the first longitudinal position of the actuation sleeve substantially corresponds with an upper longitudinal extent of at least one arcuate path formed at least partially along the circumference of the pin guide sleeve.

15. The expandable reamer of claim 14, wherein the actuation sleeve-biasing element and the reduced cross-sectional orifice are sized and configured so that a drilling fluid flow rate of a second selected value lower than the first selected value causes the pin and actuation sleeve to be longitudinally displaced about halfway between the first longitudinal position of the actuation sleeve and the second longitudinal position of the actuation sleeve.

16. The expandable reamer of claim 9, wherein the actuation sleeve is sized and configured so that at the first longitudinal position, an upper longitudinal end of the actuation sleeve is above or within the longitudinal extent of the at least one laterally movable blade, and at the second longitudinal position, the actuation sleeve is positioned longitudinally outside of the longitudinal extent of the at least one laterally movable blade.

17. The expandable reamer of claim 9, wherein the second longitudinal position of the actuation sleeve increases a size of the drilling fluid flow path through the expandable reamer by way of selectively allowing drilling fluid communication with at least one alternative drilling fluid flow path while allowing drilling fluid to communicate with the at least one laterally movable blade.

18. The expandable reamer of claim 1, wherein the actuation sleeve is configured to accept or interact with a restriction element for preventing flow of drilling fluid therethrough to allow drilling fluid communication with the at least one laterally movable blade.

19. The expandable reamer of claim 18, wherein the actuation sleeve is configured to increase a size of the drilling fluid flow path through the expandable reamer by way of allowing drilling fluid communication with at least one alternative drilling fluid flow path subsequent to a restriction element preventing the flow of drilling fluid through the actuation sleeve.

20. The expandable reamer of claim 18, wherein the restriction element comprises a ball sized and configured to engage the actuation sleeve at a seating surface complementarily sized and configured to substantially prevent the flow of drilling fluid therethrough and cause displacement of the actuation sleeve within the expandable reamer to a position that allows communication between drilling fluid and the at least one laterally movable blade.

21. The expandable reamer of claim 1, wherein the at least one laterally movable blade comprises a plurality of laterally movable blades.

22. The expandable reamer of claim 21, wherein a cross-sectional shape of each of the plurality of laterally movable blades in a geometric plane substantially perpendicular to the lateral movement thereof, respectively, comprises at least one of an oval, elliptical, and arcuate shape.

23. The expandable reamer of claim 21, wherein a cross-sectional shape of a portion of each of the plurality of laterally movable blades capable of being positioned laterally outside of the tubular body in a geometric plane substantially perpendicular to the direction of movement thereof comprises at least one of an oval, elliptical, and arcuate shape.

24. The expandable reamer of claim 21, wherein the plurality of laterally movable blades comprises a first plurality of laterally movable blades configured within the tubular body to extend to a first outermost lateral position and a second plurality of laterally movable blades configured within the tubular body to extend to a second outermost lateral position.

25. The expandable reamer of claim 1, wherein the actuation sleeve comprises an actuation sleeve lip configured to engage a wireline tool.

26. The expandable reamer of claim 1, wherein the outermost lateral position of the at least one laterally movable blade is adjustable by way of an adjustable blade spacer element.

27. The expandable reamer of claim 26, wherein the adjustable blade spacer element comprises a replaceable pin or block.

28. The expandable reamer of claim 1, wherein the at least one laterally movable blade comprises a taper at its upper outer longitudinal end.

29. The expandable reamer of claim 21, wherein each of the plurality of laterally movable blades comprises a taper at its upper outer longitudinal end.

30. The expandable reamer of claim 1, wherein the expanded diameter of the expandable reamer exceeds the initial diameter of the expandable reamer by more than 20%.

31. The expandable reamer of claim 30, wherein the at least one laterally movable blade comprises a plurality of laterally movable blades.

32. The expandable reamer of claim 31, wherein each of the plurality of laterally movable blades is disposed so that its longitudinal extent does not overlap with the longitudinal extent of another of the plurality of laterally movable blades.

33. The expandable reamer of claim 31, wherein the plurality of blades is disposed about the longitudinal axis of the tubular body circumferentially asymmetrically.

34. The expandable reamer of claim 30, wherein the expanded diameter of the expandable reamer exceeds the initial diameter of the expandable reamer by about 40%.

35. The expandable reamer of claim 34, wherein the initial diameter of the expandable reamer is about 10.5 inches and the expanded diameter of the expandable reamer is about 14.75 inches.

36. The expandable reamer of claim 25, wherein the plurality of laterally movable blades is disposed about the longitudinal axis of the tubular body circumferentially asymmetrically.

37. The expandable reamer of claim 1, further comprising a replaceable bearing pad disposed proximate to a lower longitudinal end of the at least one laterally movable blade.

38. The expandable reamer of claim 37, wherein the replaceable bearing pad comprises at least one of hardfacing, diamond, tungsten carbide, and superabrasive materials.

39. The expandable reamer of claim 37, wherein the replaceable bearing pad is affixed to the expandable reamer by way of two or more removable lock rods extending longitudinally through the tubular body thereof.

40. The expandable reamer of claim 1, further comprising at least one laterally movable bearing pad.

41. The expandable reamer of claim 40, wherein a vector sum of lateral cutting forces of the at least one cutting structure carried on the blades of the plurality is directed toward the at least one laterally movable bearing pad.

42. The expandable reamer of claim 40, wherein the at least one laterally movable bearing pad includes a first laterally movable bearing pad configured and mounted to the tubular body to extend to an outermost lateral position and a second laterally movable bearing pad configured and mounted to the tubular body to extend to a different outermost lateral position.

43. The expandable reamer of claim 40, wherein the at least one laterally movable bearing pad comprises a plurality of laterally movable bearing pads.

44. The expandable reamer of claim 43, wherein the plurality of laterally movable bearing pads is configured and mounted to the tubular body to extend to a diameter of the pilot drill bit.

45. The expandable reamer of claim 1, further comprising a seal assembly disposed within the expandable reamer between two surfaces configured to move relative to one another comprising a T-shaped seal adjacent at least one backup seal member having a nonplanar wiping surface.

46. The expandable reamer of claim 45, wherein the nonplanar wiping surface comprises a ridged surface.

47. The expandable reamer of claim 46, wherein the T-shaped seal is positioned between two backup seals having nonplanar wiping surfaces comprising ridged surfaces.

48. The expandable reamer of claim 45, wherein the seal assembly is configured to seal a portion of the at least one laterally movable blade.

49. The expandable reamer of claim 45, wherein the seal assembly is configured to seal a portion of the actuation sleeve.

50. The expandable reamer of claim 1, further comprising:

a seal assembly disposed within the expandable reamer exposed at least partially to the drilling fluid; and

a compensator system configured to equalize pressure within the seal assembly and a pressure of the drilling fluid.

51. The expandable reamer of claim 50, wherein the compensator system is disposed within the at least one laterally movable blade.

52. The expandable reamer of claim 1, further comprising a compensator system configured to supply lubricant and equalize the pressure therein in relation to drilling fluid pressure to a seal within the expandable reamer.

53. The expandable reamer of claim 52, wherein the compensator system is disposed within the at least one laterally movable blade.

54. The expandable reamer of claim 1, wherein the drilling fluid flow path is sized and configured to produce a perceptible drilling fluid pressure response indicating an operational state of the expandable reamer.

55. The expandable reamer of claim 54, wherein the drilling fluid flow path is sized and configured to produce a perceptible drilling fluid pressure response indicating allowance or prevention of drilling fluid communication with the at least one laterally movable blade.

56. The expandable reamer of claim 54, wherein the drilling fluid flow path comprises a port wherein drilling fluid flow therethrough is inhibited in relation to a lateral position of the at least one movable blade.

57. The expandable reamer of claim 54, wherein the drilling fluid flow path comprises at least one of a burst disc, shear pin, or pressure accumulator.

58. The expandable reamer of claim 1, wherein the at least one laterally movable blade is retained within the expandable reamer by way of two or more removable lock rods extending longitudinally along and through the tubular body thereof.

59. The expandable reamer of claim 58, wherein the two or more removable lock rods extend longitudinally through a spacing element configured to retain the at least one laterally movable blade within the tubular body of the expandable reamer.

60. The expandable reamer of claim 1, further comprising at least one ovoid structure carried by the at least one laterally movable blade configured to inhibit the at least one cutting structure experiencing excessive or damaging contact.

61. The expandable reamer of claim 60, wherein the at least one cutting structure comprises a plurality of cutting structures and wherein the at least one ovoid structure comprises first and second ovoid structures carried by the at least one laterally movable blade configured to inhibit the plurality of cutting structures experiencing excessive or damaging contact.

62. The expandable reamer of claim 61, wherein the first ovoid structure is disposed at a first longitudinal position on the at least one laterally movable blade and the second ovoid structure is disposed at a second longitudinal position on the at least one laterally movable blade.

63. The expandable reamer of claim 60, wherein the at least one ovoid structure carried by the at least one laterally movable blade comprises at least one of tungsten carbide and a superabrasive material.

64. An expandable reamer for drilling a subterranean formation, comprising:

a tubular body having a longitudinal axis and a leading end thereof for connecting to a drill bit and a trailing end thereof for connecting to a drill string;

a plurality of generally radially and longitudinally extending blades carried by the tubular body, carrying at least one cutting structure thereon, wherein at least one blade of the plurality of blades is laterally movable;

a blade-biasing element for holding the at least one laterally movable blade at an innermost lateral position with a force, the innermost lateral position corresponding to an initial diameter of the expandable reamer;

a structure for retaining the at least one laterally movable blade at an outermost lateral position, the outermost lateral position corresponding to an expanded diameter of the expandable reamer; and

a separation element substantially separating drilling fluid from another fluid in communication with the at least one movable blade and configured to communicate force or pressure developed by way of the drilling fluid to the another fluid.

65. The expandable reamer of claim 64, wherein the at least cutting structure comprises a plurality of superabrasive cutters.

66. The expandable reamer of claim 64, wherein a cross-sectional shape of the at least one laterally movable blade in a geometric plane substantially perpendicular to the lateral movement thereof comprises at least one of an oval, elliptical, and arcuate shape.

67. The expandable reamer of claim 64, wherein a cross-sectional shape of a portion of the at least one laterally movable blade capable of being positioned laterally outside of the tubular body in a geometric plane substantially perpendicular to the direction of movement thereof comprises at least one of an oval, elliptical, and arcuate shape.

68. The expandable reamer of claim 64, wherein the separation element comprises one of a piston and a membrane.

69. The expandable reamer of claim 64, wherein the separation element is sized and configured to develop or transmit a selected magnitude of pressure or force upon the at least one movable blade.

70. The expandable reamer of claim 64, further comprising at least one laterally movable bearing pad.

71. The expandable reamer of claim 70, wherein a vector sum of lateral cutting forces of the at least one cutting structure carried on the blades of the plurality is directed toward the at least one laterally movable bearing pad.

72. The expandable reamer of claim 64, wherein the expanded diameter of the expandable reamer exceeds the initial diameter of the expandable reamer by more than 20%.

73. The expandable reamer of claim 72, wherein the at least one laterally movable blade comprises a plurality of laterally movable blades.

74. The expandable reamer of claim 73, wherein each of the plurality of laterally movable blades is disposed so that its longitudinal extent does not overlap with the longitudinal extent of another of the plurality of laterally movable blades.

75. The expandable reamer of claim 72, wherein the expanded diameter of the expandable reamer exceeds the initial diameter of the expandable reamer by about 40%.

76. The expandable reamer of claim 75, wherein the initial diameter of the expandable reamer is about 10.5 inches and the expanded diameter of the expandable reamer is about 14.75 inches.

77. The expandable reamer of claim 64, wherein the at least one laterally movable blade is retained within the expandable reamer by way of two or more removable lock rods extending longitudinally along and through the tubular body thereof.

78. The expandable reamer of claim 77, wherein the two or more removable lock rods extend longitudinally through a spacing element configured to retain the at least one laterally movable blade within the tubular body of the expandable reamer.

79. The expandable reamer of claim 64, further comprising at least one ovoid structure carried by the at least one laterally movable blade configured to inhibit the at least one cutting structure experiencing excessive or damaging contact.

80. The expandable reamer of claim 79, wherein the at least one cutting structure comprises a plurality of cutting structures and wherein the at least one ovoid structure comprises first and second ovoid structures carried by the at least one laterally movable blade configured to inhibit the plurality of cutting structures experiencing excessive or damaging contact.

81. The expandable reamer of claim 80, wherein the first ovoid structure is disposed at a first longitudinal position on the at least one laterally movable blade and the second ovoid structure is disposed at a second longitudinal position on the at least one laterally movable blade.

82. The expandable reamer of claim 79, wherein the at least one ovoid structure carried by the at least one laterally movable blade comprises at least one of tungsten carbide and a superabrasive material.

83. An expandable reamer for drilling a subterranean formation, comprising:

a tubular body having a longitudinal axis and a leading end thereof for connecting to a pilot drill bit and a trailing end thereof for connecting to a drill string;

a plurality of generally radially and longitudinally extending blades carried by the tubular body, carrying at least one cutting structure thereon, wherein at least one blade of the plurality of blades is laterally movable;

a blade-biasing element for holding the at least one laterally movable blade at an innermost lateral position with a force, the innermost lateral position corresponding to an initial diameter of the expandable reamer;

a structure for retaining the at least one laterally movable blade at an outermost lateral position, the outermost lateral position corresponding to an expanded diameter of the expandable reamer;

a drilling fluid path for communicating drilling fluid through the expandable reamer without interaction with the at least one movable blade; and

a chamber in communication with the at least one movable blade, substantially sealed from the drilling fluid path and configured for developing pressure therein.

84. The expandable reamer of claim 83, wherein the at least cutting structure comprises a plurality of superabrasive cutters.

85. The expandable reamer of claim 83, wherein a cross-sectional shape of the at least one laterally movable blade in a geometric plane substantially perpendicular to the lateral movement thereof comprises at least one of an oval, elliptical, and arcuate shape.

86. The expandable reamer of claim 83, wherein a cross-sectional shape of a portion of the at least one laterally movable blade capable of being positioned laterally outside of the tubular body in a geometric plane substantially perpendicular to the direction of movement thereof comprises at least one of an oval, elliptical, and arcuate shape.

87. The expandable reamer of claim 83, wherein the chamber is configured to be operably coupled to and pressurized by way of a downhole pump or turbine.

88. The expandable reamer of claim 83, further comprising at least one laterally movable bearing pad.

89. The expandable reamer of claim 88, wherein a vector sum of lateral cutting forces of the at least one cutting structure carried on the blades of the plurality is directed toward the at least one laterally movable bearing pad.

90. The expandable reamer of claim 83, wherein the expanded diameter of the expandable reamer exceeds the initial diameter of the expandable reamer by more than 20%.

91. The expandable reamer of claim 84, wherein the at least one laterally movable blade comprises a plurality of laterally movable blades.

92. The expandable reamer of claim 91, wherein each of the plurality of laterally movable blades is disposed so that its longitudinal extent does not overlap with the longitudinal extent of another of the plurality of laterally movable blades.

93. The expandable reamer of claim 90, wherein the expanded diameter of the expandable reamer exceeds the initial diameter of the expandable reamer by about 40%.

94. The expandable reamer of claim 93, wherein the initial diameter of the expandable reamer is about 10.5 inches and the expanded diameter of the expandable reamer is about 14.75 inches.

95. The expandable reamer of claim 83, wherein the at least one laterally movable blade is retained within the expandable reamer by way of two or more removable lock rods extending longitudinally along and through the tubular body thereof.

96. The expandable reamer of claim 95, wherein the two or more removable lock rods extend longitudinally through a spacing element configured to retain the at least one laterally movable blade within the tubular body of the expandable reamer.

97. The expandable reamer of claim 83, further comprising at least one ovoid structure carried by the at least one laterally movable blade configured to inhibit the at least one cutting structure experiencing excessive or damaging contact.

98. The expandable reamer of claim 97, wherein the at least one cutting structure comprises a plurality of cutting structures and wherein the at least one ovoid structure comprises first and second ovoid structures carried by the at least one laterally movable blade configured to inhibit the plurality of cutting structures experiencing excessive or damaging contact.

99. The expandable reamer of claim 98, wherein the first ovoid structure is disposed at a first longitudinal position on the at least one laterally movable blade and the second ovoid structure is disposed at a second longitudinal position on the at least one laterally movable blade.

100. The expandable reamer of claim 97, wherein the at least one ovoid structure carried by the at least one laterally movable blade comprises at least one of tungsten carbide and a superabrasive material.

101. A method of reaming a borehole in a subterranean formation, comprising:

disposing an expandable reamer apparatus within the subterranean formation, the expandable reamer apparatus including a plurality of blades and having at least one laterally movable blade, each blade carrying at least one cutting structure;

biasing the at least one laterally movable blade to a laterally innermost position corresponding to an initial diameter of the expandable reamer;

flowing drilling fluid through the expandable reamer via a drilling fluid flow path while preventing drilling fluid from communicating with the at least one laterally movable blade;

allowing drilling fluid to communicate with the at least one laterally movable blade;

causing the at least one laterally movable blade to move to an outermost lateral position corresponding to an expanded diameter of the expandable reamer by way of allowing drilling fluid to communicate with the at least one laterally movable blade; and

reaming a borehole in the subterranean formation by rotation and displacement of the expandable reamer within the subterranean formation.

102. The method of claim 101, wherein preventing drilling fluid from communicating with the at least one laterally movable blade comprises positioning an actuation sleeve to prevent drilling fluid communication with the at least one laterally movable blade.

103. The method of claim 102, wherein allowing drilling fluid to communicate with the at least one laterally movable blade comprises positioning an actuation sleeve to allow drilling fluid communication with the at least one laterally movable blade.

104. The method of claim 103, wherein positioning the actuation sleeve to allow or prevent drilling fluid communication with the at least one laterally movable blade comprises positioning the actuation sleeve by way of moving a pin disposed within a groove of a pin guide sleeve.

105. The method of claim 103, further comprising developing a force upon the actuation sleeve by way of flowing drilling fluid through a reduced cross-sectional orifice.

106. The method of claim 102, further comprising:

restricting drilling fluid flow through the actuation sleeve.

107. The method of claim 102, further comprising causing the actuation sleeve to move to a position wherein the longitudinal extent thereof does not coincide with the longitudinal extent of the at least one laterally movable blade.

108. The method of claim 101, further comprising generating a drilling fluid pressure response associated with an operational condition of the expandable reamer.

109. The method of claim 108, further comprising generating a drilling fluid pressure response by way of relatively rapidly reducing a size of the drilling fluid flow path.

110. The method of claim 108, further comprising identifying the drilling fluid pressure response.

111. The method of claim 101, wherein disposing the expandable reamer within the subterranean formation comprises disposing the expandable reamer through a casing section with an inner diameter that is smaller than the expanded diameter of the expandable reamer.

112. The method of claim 101, further comprising increasing a size of the drilling fluid flow path through the expandable reamer subsequent to allowing drilling fluid to communicate with the at least one laterally movable blade.

113. A method of reaming a borehole in a subterranean formation, comprising:

disposing an expandable reamer apparatus within the subterranean formation, the expandable reamer apparatus including a plurality of blades and having at least one laterally movable blade, each blade carrying at least one cutting structure;

biasing the at least one laterally movable blade to a laterally innermost position corresponding to an initial diameter of the expandable reamer;

flowing drilling fluid through the expandable reamer;

preventing drilling fluid from communicating with the at least one laterally movable blade;

causing the at least one laterally movable blade to move to an outermost lateral position corresponding to an expanded diameter of the expandable reamer by way pressurizing another fluid in communication with the at least one laterally movable blade; and

reaming a borehole in the subterranean formation by rotation and displacement of the expandable reamer within the subterranean formation.

114. The method of claim 113, wherein pressurizing the another fluid in communication with the at least one laterally movable blade comprises operating a downhole pump or turbine.

115. A method of reaming a borehole in a subterranean formation, comprising:

disposing an expandable reamer apparatus within the subterranean formation, the expandable reamer apparatus including a plurality of blades and having at least one laterally movable blade, each blade carrying at least one cutting structure;

biasing the at least one laterally movable blade to a laterally innermost position corresponding to an initial diameter of the expandable reamer;

flowing drilling fluid through the expandable reamer;

preventing drilling fluid from communicating with the at least one laterally movable blade by disposing a separation element between the drilling fluid and another fluid in communication with the at least one laterally movable blade;

causing the at least one laterally movable blade to move to an outermost lateral position corresponding to an expanded diameter of the expandable reamer by transmitting force or pressure developed on the separation element by way of drilling fluid to the at least one laterally movable blade by way of the another fluid in communication therewith; and

reaming a borehole in the subterranean formation by rotation and displacement of the expandable reamer within the subterranean formation.